Renewable and Sustainable Energy Reviews 34 (2014) 325–336

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Environmental Kuznets curve in an open economy: A bounds testing and causality analysis for Tunisia

Muhammad Shahbaz [a,*], Naceur Khraief [b], Gazi Salah Uddin [c], Ilhan Ozturk [d,1]

[a] Department of Management Sciences, COMSATS Institute of Information Technology, Lahore, Pakistan
[b] Faculty of Economic Science and Management of Sousse, University of Sousse, Tunisia
[c] Department of Management & Engineering, Linköping University, SE-581 83 Linköping, Sweden
[d] Faculty of Economics and Administrative Sciences, Cag University, 33800 Mersin, Turkey

ARTICLE INFO

Article history:
Received 17 November 2012
Received in revised form
3 February 2014
Accepted 9 March 2014
Available online 30 March 2014

Keywords:
EKC
Energy
Tunisia

ABSTRACT

The environmental Kuznets curve hypothesis posits that in the early stages of economic growth environmental degradation and pollution increase. However, as a nation reaches a certain level of income, measured in per capita terms, the trend reverses. The postulated relationship thus produces an inverted U-shaped curve. The topic has drawn much academic interest in the context of developed and emerging nations.

The aim of this paper is to investigate the existence of environmental Kuznets curve (EKC) in case of Tunisia using annual time series data for the period of 1971–2010. The ARDL bounds testing approach to cointegration is applied to test long run relationship in the presence of structural breaks and vector error correction model (VECM) to detect the direction of causality among the variables. The robustness of causality analysis has been tested by applying the innovative accounting approach (IAA). The findings of this paper confirmed long run relationship between economic growth, energy consumption, trade openness and CO_2 emissions. The results also indicated the existence of EKC confirmed by the VECM and IAA approaches. The study has significant contribution for policy implications to curtail energy pollutants by implementing environment friendly regulations to sustain economic development in Tunisia.

Contents

1. Introduction

Over the past two decades, climate change due to global warming has risen in prominence as one of the most significant challenges facing the world. Theoretically the existence of an inverted-U shaped relationship between real GDP per capita and measures of environmental degradation such as SO_2 and/or CO_2 emissions is defined as the environmental Kuznets curve (EKC) hypothesis. The EKC hypothesis states that environmental degradation will initially increase as per capita income rises. At some point, however, the degradation will begin to decrease, forming an inverted U-shaped curve. In the context of climate change, this indicates that CO_2 emissions from a country will decrease as further economic growth occurs. The existence of EKC has been

* Corresponding author.
E-mail addresses: shahbazmohd@live.com (M. Shahbaz), nkhraief@gmail.com (N. Khraief), gazi.salah.uddin@liu.se (G.S. Uddin), ilhanozturk@cag.edu.tr (I. Ozturk).
[1] Tel./fax: +90 324 6514828.

http://dx.doi.org/10.1016/j.rser.2014.03.022
1364-0321/

actively examined for both developed and developing countries. The validity of EKC itself is debatable as it may depend on the unique characteristics of a country. Energy consumption, pollutant emissions and economic growth may be closely interrelated.

While globalization has augmented, economic growth in Tunisia in emerging economies is an interesting case where it faces the difficulty to fulfill the needs of energy demand. Trade may increase pollution in developing countries due to the increased production of emission-intensive goods for export to developed nations. Since 1986 Tunisia runs a program of economic liberalization and structural adjustment supported by the International Monetary Fund (IMF). Thus, after a period marked by an economic growth of 2.9% at constant prices (81–86), the annual economic growth could reach much higher values, with 4.4% between 1988 and 1999, hereby confirmed in the following years to reach an average annual growth of 4,6% between 2000 and 2010 (WDI [65]). At present, Tunisia has a diverse economy, ranging from agriculture, mining, manufacturing, and petroleum products, to tourism. One of Tunisia's outstanding characteristics is its remarkable economic development, sustained over the past two decades driven by a process of market liberalization and integration into world markets. The European Union (EU) represents the first trading partner of Tunisia. More than two-thirds of the Tunisian imports in 2008 originated from the EU and almost three quarters of the Tunisian exports were targeted to the EU. By subsequently removing all trade barriers, Tunisia became the first Mediterranean country to enter into a free trade area with the EU in 2008. Tunisia's main exports to the EU in 2011 were manufactured products 78.5% (of which 24.7% clothing and 33.6% machinery and transport equipment), then energy (16.3%) and agricultural products (4.7%). Major imports from the EU were machinery and transport equipment (35.8%), energy (13.6%) and chemicals (10%) (European Commission – Tunisia Trade Statistics [15]). In order to implementation of the trade liberalization policy in Tunisia, economic growth and energy consumption is rising steadily. Therefore, the impacts will be an increase in the costs of energy supply and emissions of greenhouse gases (GHG) in the country.

In this paper, we attempt to examine the causal relationships between income, energy consumption and carbon emissions in Tunisia using annual time series data by incorporating trade as potential determinant of energy emissions. We apply newly developed methods based on simulations that are robust with respect to the violation of statistical assumptions, especially when the sample size is small. In addition, the Granger causality test applied within the vector error correction model (VECM) to understand the short run dynamics as well as innovative accounting approach (IAA). The findings of this study would help policymakers to develop comprehensive energy and environmental policies to sustain economic growth in Tunisia. The contribution of this paper is that it takes into account a number of potential advantages compare to the earlier literature. The empirical analysis of this paper incorporates both cointegration methods such as Johansen and Juselius and the autoregressive distributive lag modeling (ARDL) or the ARDL bounds testing approach in the presence of structural breaks stemming in the series. This is the first study for Tunisia where both the methods applied in order to make the result robust. Second, the unit root properties are examined by applying structural breaks. Third, we provide empirical evidence of the EKC by including trade as an additional determinant of CO_2 emissions in case of Tunisia. Finally, trade openness has an important role on higher energy consumption and income in Tunisia. Therefore, policy makers have to include these indicators to estimate the level of energy demand for Tunisia.

The remainder of this paper is structured as follows: Section 2 provides the detailed information on Tunisia Context. Section 3 reviews the previous studies. In Section 4 we outline the econometric specification and estimation methodology and discuss how various hypotheses are tested, while Section 5 provides a discussion of our empirical results. Section 6 discusses the major findings and concludes the paper.

2. Tunisian context

The energy intensity in Tunisia stopped increasing in the 1990s and has since then declined to the lowest level in the Middle East and North American (MENA) region. However, the intensity remains high compared to some other Mediterranean countries such as Greece and Portugal. Moreover, energy expenditures – energy consumption valued at international energy prices – accounted for 12% of GDP in 2006, which is a high level compared to industrialized countries (they amount to 4% of GDP in Japan and 7% in Greece). The energy sector played vital role in financing the economic growth during this period in the country, representing in 1980 approximately 13% of national GDP and 16% of national exports. The contribution of the energy sector in economic growth has been decreasing since 1986. Currently, the energy sector accounts for approximately 5% of GDP of the country and less than 7% of total national exports. The Energy Information Administration (EIA) estimated the Tunisian oil reserves to be 430 Mbbl in 2009, ranking it 44th worldwide. In total, 57 international and national companies are involved in the exploration of oil and gas with L'Entreprise Tunisienne d'Activités Pétrolières (ETAP) being the major player (*L'Entreprise Tunisienne d'Activités Pétrolières*, ETAP [14]).

Energy consumption in Tunisia is rising steadily as a result of economic and social development. Oil and natural gas are the two main sources of energy requirements in Tunisia accounting for 48.30% and 39% respectively in 2008, whereas renewable energies do not exceed 1%. Domestic oil distribution is controlled by state-owned National Distribution and Marketing Company and domestic natural gas distribution is fully controlled by state-owned Tunisian Company *La Société Tunisienne de l'Electricité et du Gaz* (STEG) (Law no. 62-8/Law no. 62-16/Law no. 70-58/Law no. 96-27). Oil and natural gas exploration are controlled by state-owned Tunisian National Oil Company, *L'Entreprise Tunisienne d'Activités Pétrolières*.[2] The country produced about 81,000 barrels per day (bbl/day) of crude oil in 2009. This represents a decline of one-third from Tunisia's peak output i.e., 120,000 bbl/d over the period of 1982–1984. Crude oil production has declined marginally in the past decade. Presently, the Tunisia's oil production capacity cannot meet the domestic consumption demand. The domestic consumption has increased from 83,000 barrels per day in 1999 to about 107,600 barrels per day in 2009. Tunisian energy consumption grew by 500% between 1971 and 2010. At the same period, domestic energy production grew by only 47% (World Bank, World Development Indicators [65]).

The country no longer exports crude oil as domestic consumption has risen considerably in recent years. The country's low refining capacity has led the country to import refined petroleum products to meet its demands. Industry is the biggest energy consumer (36% of total energy). Transport is another significant sector for consumption, accounting for 30% of energy use. The building sector is also significant and growing to eventually become the biggest consumer of energy. Construction building materials are responsible for 60% of the energy of the industrial sector. Tunisia became a net oil importer for the first time in 2000 and currently it imports over half of its petroleum product

[2] The ETAP is the state-owned industrial and commercial company, created by the law (No. 72-22) of 1972.

demand. Compared to its neighboring countries, domestic fossil energy sources in Tunisia are limited. Yet, increasing effort in oil production resulted in 85,887 barrels per day in 2007 compared to 76,748 barrels per day in 2005 (EIA [72]).

Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. The variable is the percentage of global CO_2 emissions that are produced by the country in any given year. Although a Party to the Kyoto Protocol, Tunisia, as a developing country, has no GHG reduction binding commitment under this Protocol (Tunisia has ratified the Kyoto Protocol in 2003). However, data on CO_2 emissions per capita level has increased over time. The main source of GHG emissions in Tunisia is the energy sector (52.9%), followed by agriculture (20.8%), industrial processes (9.8%), forests (12.9%) and waste (3.6%) (Ministry of the Environment and Sustainable Development – *Ministère de l'Environnement et du Développement Durable* [33]).

The degree of carbon intensity of Tunisia's economy is quite sensitive to whether one uses market or purchasing power parity (PPP) exchange rates for converting GDP into US dollars. At PPP exchange rates, in 2007 Tunisia generated 0.309 kg CO_2 emissions per unit of $GDP (World Bank [65]). Compared to other countries in the Arab world, Tunisia has the lowest level of carbon intensity (Algeria 0.532, Egypt 0.455, Lebanon 0.31, Morocco 0.364, Saudi Arabia 0.733 and Syria 0.775). Although, differences in this ratio across countries reflect in part structural characteristics of each economy, energy efficiency of particular sectors of the economy, and differences in fuel mixes. Tunisia also has the lowest ratio of CO_2 emissions to total energy use 2.7 metric t CO_2 per ton of energy oil equivalent versus 3.8 for Algeria, 2.74 for Egypt, 3.34 for Lebanon, 2.7 for Arabia Saudi, 3.23 for Morocco and 3.56 for Syria (IEA [71]).

In Tunisia, energy generation and the transport sector are among the major contributors to air pollution, at 31% and 30% respectively. The transport sector is the top contributor of CO_2 and lead emissions. CO_2 emissions account for 92% of the total GHG emissions, while methane emissions account for 7%, and nitrogen oxide for 1%. GHG emissions of CO_2 from the transport sector rose from 3.4 million t to 5.8 million t between 1994 and 2002, with an annual increase rate of 9%, but transport CO_2 emissions have declined to reach 4.6 million t in 2009. In 2008 an energy conservation program for the period 2008–2011 was introduced. It contains measures that are estimated to save 20% of energy use by the end of the program. Through actions in energy efficiency and renewable energies, 8 $MtCO_2eq$ are planned to be saved by the end of 2011 (Tunisian National Agency for Energy Conservation [58]).

Furthermore, in 2006 the National Fund for Energy Conservation was implemented, which financially supports energy conservation policies in Tunisia. This fund is fed by taxation of inefficient air-conditioning appliances and cars and supplies also other sectors like the industrial sector. In addition to this legislation, support programs are in place like the successfully Prosol (a subsidy scheme for the utilization of solar thermal panels in the residential sector) and others, while further programs are planned. Just recently, Tunisian Solar Plan was introduced with the aim to save 1.3 $MtCO_2eq$ per year until 2016. The Tunisian Solar Plan (TSP) is the framework for the Tunisian energy policy; within this framework, numerous projects and measures are planned (Tunisian National Agency for Energy Conservation [59]).

Last but not least, Fig. 1 shows the similar trends in energy consumption per capita, CO_2 emissions per capita and real GDP per capita. Following real GDP and energy consumption per capita, growth rate in CO_2 emissions over the past decade is faster than that of previous ones (since the structural adjustment reforms adopted by the country in 1986, Gradually liberalizing Tunisia's trade policies and integrating it into the international economy). In fact, there is a positive correlation between real GDP growth and energy consumption that has a positive significant impact on carbon dioxide emissions (indicating CO_2 emissions have accelerated in recent years). The dynamic link between these variable justify our further estimation.

3. Review of literature

Existing research in the empirical literature, investigates the causal relationship between economic growth, energy consumption and environmental quality, of which CO_2 emissions has important

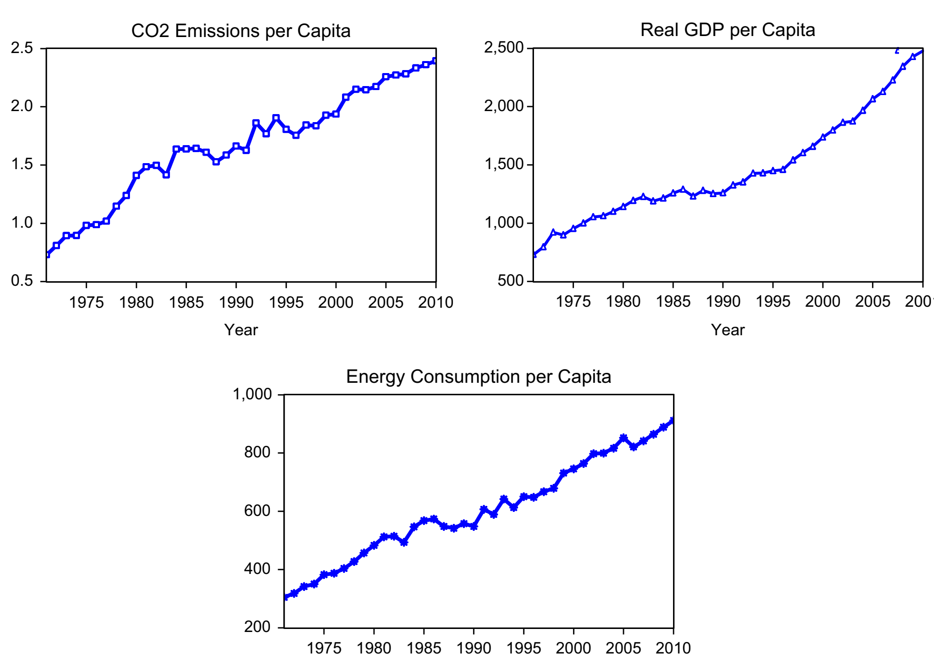


Fig. 1. Trends in energy consumption, CO_2 emissions and GDP.

implications. The idea of inverted U-shaped relationship, pioneered by Kuznets [27], was investigated using cross-country relationships (Grossman and Krueger [21]; Stern et al. [55]), or time-series for specific countries, Egli [12]; or panel data, Dijkgraaf and Vollebergh [11]. However, the results of such research have been contradictory and inconclusive.

For example, energy use plays a crucial role in any industrial economy. Working with the Chinese provincial data from 1985 to 2005, Song et al. [54] re-examined the validity of the EKC hypothesis in China using panel cointegration approach and found that there is a long-run relationship between per capita emissions of waste gas, waste water, and solid wastes and, per capita GDP and pollutants are inverse U-shaped in China. Using the similar method for applying the ASEAN over the period 1980–2006, Lean and Smyth [28] found that long-run unidirectional causality exists from energy consumption and CO_2 emissions to income. Similarly, Ang [1] confirmed that the EKC hypothesis is satisfied in France, by incorporating the commercial perspective of energy consumption. In the same way applying the similar variables; Ang [2] found a stable long-run relationship for Malaysia. In addition, Nasir and Rehman [36] found that in long-run, EKC hypothesis holds in Pakistan and Shahbaz et al. [50] validated their results by conducting another study in case of Pakistan. In case of Indonesia, Saboori et al. [45] reported that the EKC is found while trade openness is the major contributor of CO_2 emissions after energy consumption and economic growth. Saboori et al. [46] established long run relationship between energy consumption, economic growth and energy emissions using Malaysian data. They validated the existence of the EKC and CO_2 emissions in Malaysia are the cause of economic growth. Yeh [63] used the quantiles regressions using the data of developing and developed countries and reported the existence of the EKC by controlling other macroeconomic variables. In case of Romania, Shahbaz et al. [52] confirmed long run relationship between economic growth, energy consumption and energy pollutants. Their empirical evidence also found that the EKC exists both for long-and-short runs. Moreover, energy consumption is a major contributor to energy pollutants. Democratic regime shows her significant contribution to decline CO_2 emissions through effective implementation of economic policies and financial development improves environment i.e., reduces CO_2 emissions by redirecting the resources to environment friendly projects. Later on, Uddin et al. [61] investigated the relationship between energy consumption, economic growth, trade openness and CO_2 emissions in the case of Sri Lanka. Their results found that economic growth Granger causes energy consumption and CO_2 emissions. Recently, Tiwari et al. [57] also confirmed the existence of the environmental Kuznets curve in India and coal consumption is the major contributor to degrade environmental quality.

The emerging economics are less concerned about the relationship between trade openness and environmental quality. The explanation of this issue explained that low environmental regulation has a competitive advantage in the production of pollution intensive-products, increasing exports and reducing imports of such products. The reverse case exists in the context of advanced economics. Starting with Copeland and Taylor [9,10] found that cross-country differences in income-induced environmental regulations to predictions on trade patterns and pollution. Antweiler et al. [4] investigated the impact of trade openness on environment and found that the changes in production technologies follow the trade liberalization. Gamper-Rabindran and Jha [18] studied the causal relationship between trade liberalization and environment in case of Indian economy. They found that exports and foreign direct investment grew in the more-polluting sectors relative to the less-polluting sectors. The similar results were found in Vietnam and Turkey (Mani and Jha [31]; Akbostanci et al. [1]). Furthermore, Frankel and Rose [17] found that, for a given level of income, trade openness affects on several measures of air pollution such as SO_2 and NO*x*. The study performed by Grossman and Krueger [21] is pioneering in this regard, while additional research along this line of inquiry has also been addressed by Lucas et al. [29], Wyckoff and Roop [62], Nahman and Antrobus [34], and others. The results of these studies, however, are inconclusive in terms of the relationship between trade and environmental quality. In a more recent study, Halicioglu [22] confirmed that for Turkish economy, income was the most crucial determinant of CO_2 emissions, followed by energy consumption and trade. Shahbaz et al. [74] investigated the existence of the EKC by incorporating globalization in CO_2 emissions function using data of Turkey. Their analysis confirmed the presence of the EKC in Turkey and globalization also increases CO_2 emissions. Shahbaz et al. [75] examined the relationship between economic growth, energy consumption and CO_2 emissions in case of Romania. They found the presence of the EKC and energy consumption is major contributor in CO_2 emissions. Shahbaz et al. [76] inspected the impact of energy consumption, economic growth and trade openness on CO_2 emissions in case of Indonesia. Their empirical exercise unveiled that economic growth and energy consumption add in CO_2 emissions but trade openness declines it. Shahbaz and Leitão [77] tested the validation of EKC in Portugal by applying the Newey-West test. They found that trade openness increases CO_2 emissions and the EKC is present.

By reviewing the energy economics literature, it is clear that there is an extensive literature on the nexus between income, energy consumption and emissions. However, it is an important discussion with the findings of the country specific study. Recent studies, Sari and Soytas [48] used annual data from 1971 to 2002 to reexamine the inter-temporal link between energy consumption and income in six developing countries (Indonesia, Iran, Malaysia, Pakistan, Singapore, and Tunisia) in a production function framework. They found that growth of income and energy consumption contains considerable information to predict each other applying the generalized variance decompositions and generalized impulse response. This study suffers not only from small sample size but also from methodological deficiencies such as structural break is valid in case of Tunisia.

In case of Tunisia, working with the annual data over the period of 1971–2004, Belloumi [7] applied Johansen cointegration approach for long run and the VECM Granger causality to detect the causal relationship between the variables. They found a long-run bi-directional relationship between energy consumption and economic growth. Moreover, the study remains the problem of small sample size with the bivariate model specification. In case of small sample size, the ARDL approach is more preferable than Johansen cointegration method. Bartleet and Gounder [5] also recommended incorporating other pertinent variables that also play an important role to elucidate the growth-emissions nexus. Moreover, Fodha and Zaghdoud [16] also applied Johansen cointegration and the VECM Granger causality approaches. They reported the unidirectional causality from economic growth to CO_2 emissions in both short-run and long-run. However, the reverse is not true in this case. The sample size of this study may not represent the current situation in Tunisia. Moreover the methodological deficiencies still remain. In case of Tunisia, Shahbaz and Lean [51] find the application of the relationship between energy consumption, financial development, economic growth, industrialization and urbanization. They claim that the existence of long-run relationship among energy consumption, economic growth, financial development, industrialization and urbanization in Tunisia by applying the ARDL bounds testing and Granger causality approaches. In addition, they confirmed that

long-run bidirectional causalities are found between financial development and energy consumption, financial development and industrialization, and industrialization and energy consumption.

4. Model construction and data collection

The theoretical interaction between economic growth and energy consumption with emissions has been widely discussed in the energy economics. This suggests that the relations between economic growth and energy pollutants are termed as environmental Kuznets curve. We have augmented the model of Fodha and Zaghdoud [16] by incorporating trade openness in CO_2 emissions function to investigate the relationship between economic growth, energy consumption, trade openness and CO_2 emissions following Ang [3] for Malaysia; Halicioglu [22] for Turkey, Menyah and Wolde-Rufael [32] for South Africa and Shahbaz et al. [50] for Pakistan. Following Shahbaz [49], we converted all the series into natural logarithms to obtain efficient and consistent results. The log-linear relationship between the variables is specified as follows:

$$\ln C_t = \beta_1 + \beta_2 \ln Y_{t-1} + \beta_3 \ln Y_t^2 + \beta_4 \ln E_t + \beta_5 \ln T_t + \mu_t \quad (1)$$

where $\ln C_t$ is natural log of energy emissions per capita, $\ln Y_t$ ($\ln Y_t^2$) is economic growth proxied by real GDP per capita (square of real GDP per capita), $\ln E_t$ is for energy consumption per capita, $\ln T_t$ is trade openness per capita and μ is residual term assumed to be normally distributed in time period t. β_1 is a constant term and it can be $\beta_1 > 0$ or $\beta_1 < 0$. The hypothesis of EKC reveals that the sign of β_2 is positive i.e., $\beta_2 > 0$ i.e., economic growth has positive impact on CO_2 emissions, while that of β_3 is negative i.e., $\beta_3 < 0$ i.e., economic growth declines CO_2 emissions. It implies that economic growth increases energy emissions initially and reduces it when economy is matured. The rising demand for energy will increase energy emissions. Similarly, the sign of β_4 is positive i.e., $\beta_4 > 0$. Antweiler et al. [4] explored three channels, namely scale, technique and composition effects, through which trade openness can result in environmental improvement or deteriorations. The scale effect implies that trade liberalization causes emissions due to economic expansion which is detrimental for environment. The technique effect is believed to reduce emissions because of import of efficient and environmental friendly technologies. Finally, the composition effect signifies that trade liberalization may reduce or increase emissions depending upon whether the country has comparative advantage in cleaner or dirty industries. Hence, the composition effect can have both positive and negative impacts. Subsequently, the sign of β_5 can be positive or negative depending on which effect is stronger and dominates the other.

Annual data on real GDP per capita, energy consumption per capita, trade (exports+imports) as share of GDP, population and CO_2 emissions (kt) per capita has been collected from world development indicators (WDI-2012). The study covers the period of 1971–2010.

The drawback about the absence of structural break points has been removed by Zivot–Andrews [64] by developing three new econometric models. These econometric models are very useful in investigating the stationarity properties of the macroeconomic variables in the presence of structural break points in the series. These models allow (i) one-time change in variables at level form, (ii) one-time change in the slope of the trend component i.e., function and (iii) a model has one-time change both in intercept and trend function of the variables to be used for empirical propose. Zivot–Andrews [64] adopted three models to check the hypothesis of one-time structural break in the series as follows:

$$\Delta x_t = a + a x_{t-1} + bt + cDU_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \quad (2)$$

$$\Delta x_t = b + b x_{t-1} + ct + bDT_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \quad (3)$$

$$\Delta x_t = c + c x_{t-1} + ct + dDU_t + dDT_t + \sum_{j=1}^{k} d_j \Delta x_{t-j} + \mu_t \quad (4)$$

In the above equation dummy variable is represented by DU_t showing mean shift occurred at each point with time break, while trend shift variables are shown by DT_t. So

$$DU_t = \begin{cases} 1\ldots\text{if } t > TB \\ 0\ldots\text{if } t < TB \end{cases} \quad \text{and} \quad DU_t = \begin{cases} t - TB\ldots\text{if } t > TB \\ 0\ldots\text{if } t < TB \end{cases}$$

The null hypothesis of unit root break date is $c=0$ which indicates that series is not stationary with a drift not having information about structural break point (TB denotes the time break period) while $c<0$ hypothesis implies that the variable is found to be trend-stationary with one unknown time break. Zivot–Andrews unit root test fixes all points as potential for possible time break and does estimate through regression for all possible break points successively. Then, this unit root test selects that time break, which decreases one-sided t-statistic to test $\hat{c}(=c-1)=1$. Zivot–Andrews intimate that in the presence of end points, asymptotic distribution of the statistics is diverged to infinity point. It is necessary to choose a region where end points of sample period are excluded. Further, Zivot–Andrews suggested the trimming regions i.e., 0.15 T, 0.85 T are followed.

In order to examine long run relationship between the variables of interest, there are numerous cointegration approaches available in existing energy literature. For example, Engle and Granger [13] based on two-step procedure, Johansen [25], Johansen and Juselius [26] based on full information maximum likelihood and, Stock and Watson [56] based on dynamic ordinary least square require that all the series should be integrated at same order of integration. These cointegration approaches do not have good power properties for small sample and require large sample data for efficient and reliable empirical evidence (Gonzalo and Lee [19]). These tests seem produce misleading results regarding cointegration if series are integrated at $I(1)$ or $I(0)$ in the system (Cheung and Lai [8]). Moreover, critical values developed by Johansen cointegration approach are not suitable (Turner [60]).

The autoregressive distributed lag modeling or the ARDL bounds testing approach developed by Pesaran et al. [38] is superior to traditional cointegration approaches due to numerous aspects. For example, the ARDL bounds testing approach is suitable to apply for long run relationship between the variables if the variables are found to be stationary at level or 1st difference. The bounds testing approach to cointegration is suitable for small sample. In the presence of some endogenous variables, the ARDL bounds testing provides efficient long run estimates with valid t-statistics. The bounds approach to cointegration also seems to combine short run dynamics with long run equilibrium path having long run information following unrestricted error correction model (UECM). The UECM is modeled as follows:

$$\begin{aligned}\Delta \ln C_t = {} & \vartheta_1 + \vartheta_{DUM} DUM + \vartheta_Y \ln Y_{t-1} + \vartheta_{Y^2} \ln Y_{t-1}^2 \\ & + \vartheta_E \ln E_{t-1} + \vartheta_T \ln T_{t-1} + \sum_{j=1}^{p} \vartheta_j \Delta \ln C_{t-j} \\ & + \sum_{k=0}^{q} \vartheta_k \Delta \ln Y_{t-k} + \sum_{l=0}^{r} \vartheta_l \Delta \ln Y_{t-l}^2 + \sum_{m=0}^{s} \vartheta_k \Delta \ln E_{t-m} \\ & + \sum_{n=0}^{t} \vartheta_k \Delta \ln T_{t-n} + \mu_i \end{aligned} \quad (5)$$

where difference operator is indicated by Δ, DUM is dummy variable to capture the structural break stemming in the series and μ is residual term assumed to have normal distribution with finite variance and zero mean. Next step is to compute the ARDL

F-statistic to examine whether cointegration between the variables exists or not. Appropriate lag order of the variables is necessary to choose because value of F-statistic varies with lag order. We use Akaike information criteria (AIC) to choose suitable lag length. We apply F-test developed by Pesaran et al. [38] to examine the joint significance of estimates of lagged level of the series. The null hypothesis of no cointegration is $H_0: \vartheta_C = \vartheta_Y = \vartheta_{Y^2} = \vartheta_E = \vartheta_T = 0$ and hypothesis of cointegration is $H_0: \vartheta_C \neq \vartheta_Y \neq \vartheta_{Y^2} \neq \vartheta_E \neq \vartheta_T \neq 0$. Two asymptotic such as upper critical bound (UCB) and lower critical bound (LCB) have been generated by Pesaran et al. [38]. We accept the hypothesis of cointegration if computed F-statistic is more than upper critical bound. The hypothesis of cointegration is rejected once lower critical bound exceeds computed F-statistic. We cannot make decision about cointegration if computed F-statistic is between upper and lower critical bounds. We utilize critical bounds developed by Narayan [35] because these are suitable for small sample i.e., $T=30$ to $T=80$. It is pointed by Narayan [35] that critical bounds provided by Pesaran et al. [38] are downwards and may produce misleading results. The diagnostic tests have also been conducted to test the problem of normality, serial correlation, autoregressive conditional heteroskedasticity, white heteroskedasticity and specification of the ARDL bounds testing approach to cointegration.

We should apply the vector error correction model (VECM) to investigate the causal relationship between the variables once cointegration relationship exists between the series. It is argued by Granger [20] that the VECM is an appropriate approach to examine causality between the variables when series are integrated at $I(1)$. The empirical equation of the VECM Granger causality approach is modeled as follows:

$$(1-L)\begin{bmatrix} \ln C_t \\ \ln Y_t \\ \ln Y_t^2 \\ \ln E_t \\ \ln T_t \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} b_{11i}b_{12i}b_{13i}b_{14i}b_{15i} \\ b_{21i}b_{22i}b_{23i}b_{24i}b_{25i} \\ b_{31i}b_{32i}b_{33i}b_{43i}b_{53i} \\ b_{41i}b_{42i}b_{43i}b_{44i}b_{45i} \\ b_{51i}b_{52i}b_{53i}b_{54i}b_{55i} \end{bmatrix} \times \begin{bmatrix} \ln C_{t-1} \\ \ln Y_{t-1} \\ \ln Y_{t-1}^2 \\ \ln E_{t-1} \\ \ln T_{t-1} \end{bmatrix} + \begin{bmatrix} \alpha \\ \beta \\ \delta \\ \phi \\ \vartheta \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix} \tag{6}$$

where $(1-L)$ indicates difference operator and lagged residual term is indicated by ECT_{t-1} which is obtained from long run relationship while $\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, \varepsilon_{4t}$, and ε_{5t} are error terms. These terms are supposed to be homoscedastic i.e., constant variance. The statistical significance of coefficient of lagged error term i.e., ECT_{t-1} using t-statistic shows long run causal relationship between the variables. The short run causality is shown by statistical significance of F-statistic using Wald-test by incorporating differenced and lagged differenced of independent variables in the model. Moreover, joint significance of lagged error term with differenced and lagged differences of independent variables provides joint long-and-short runs causality. For example, $b_{12,i} \neq 0 \forall_i$ implies that economic growth Granger-causes CO_2 emissions per capita and economic growth is Granger cause of CO_2 emissions per capita shown by $b_{21,i} \neq 0 \forall_i$.

We have conducted diagnostic tests to test the classical linear regression model assumptions such as normality of error term, serial correlation, autoregressive conditional heteroskedasticity, white heteroskedasticity and specification of short model. The reliability of short run estimates is investigated by applying the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMsq) suggested by Pesaran and Shin [37].

5. Results and their interpretations

According to the ADF, PP and DF-GLS unit root tests to test the stationarity properties of the variables, it indicates that all the variables are found to be non-stationary at their level and 1st differencing, series do not show unit root problem. It implies that all the series are integrated at $I(1)$[3] i.e., variables are stationary at first difference. The problem with these unit root tests is that they do not have information about structural breaks stemming in the series. In such an environment, application of these tests provides unreliable and biased results. A study by Baum [6] forced to apply structural break unit root test to examine unit root properties of the variables. The reason is that misleading results about order of integration of the variables would be help for policy makers in articulating comprehensive economic policy. To overcome this objection, we choose to apply Zivot–Andrews (Zivot and Andrews [64]) structural break unit root test which allows having information about an unknown structural break point stemming in the time series.

The results are reported in Table 1. The results indicate that variables do have unit root problem at level with a structural break both in intercept and trend. The both variables are found to be stationary at 1st difference. This implies that the variables are integrated at $I(1)$. The unique integrating properties of the both series leads us to implement the ARDL bounds testing approach to cointegration examining the long run relationship between economic growth, energy consumption, trade openness and CO_2 emissions over the study period of 1971–2010 in case of Tunisia. An appropriate lag order of the variables is needed to apply the ARDL bounds testing. It is pointed by Lütkepohl [30] that AIC has superior power properties for small sample data compared to any lag length criterion. Our decision about lag length is based on the minimum value of AIC.[4] It is found that we cannot take lag more than 1 in such small sample data.

The next step is to estimate the ARDL F-statistic to examine the existence of cointegration between economic growth, energy consumption, trade openness and CO_2 emissions over the study period of 1971–2010 in case of Tunisia. The results of the ARDL F-statistic are reported in Table 2. The results indicate that our computed F-statistic i.e., 8.595 (11.766) and 12.096 are greater than upper critical bounds at 5 and 1% levels of significance once we used CO_2 emissions (energy consumption) and trade openness are used as forcing variables in the presence of structural breaks such as 1990 (1989) and 1976 respectively. It implies that there are three cointegration vectors and we may reject the hypothesis of no cointegration. This confirms the presence of long run relationship between CO_2 emissions, economic growth, energy consumption and trade openness in case of Tunisia.

To test the robustness of long run relationship, we also applied Johansen and Juselius [26] approach to cointegration. The results (reported in Table 3) validate that there is a long run relationship found between the variables. It implies that long run results are effective and robust. The long-run marginal impacts of economic growth, energy consumption and trade openness on CO_2 emissions are reported in Table 4. Both linear and non-linear terms of real GDP provide evidence in supporting inverted-U relationship between economic growth and CO_2 emissions. The result indicates that a 1% rise in real GDP will raise CO_2 emissions by 4.904% while negative sign of squared term seems to corroborate the delinking of CO_2 emissions and real GDP at the higher level of income. These evidences support the EKC hypothesis revealing that CO_2

[3] The results of ADF, PP and DF-GLS tests are available upon request from authors.

[4] Results are available upon request from authors.

Table 1
Zivot–Andrews structural break unit root test.

Variable	At level		At 1st difference	
	T-statistic	Time break	*T*-statistic	Time break
$\ln C_t$	−2.917 (1)	1990	−5.253 (0)**	1987
$\ln Y_t$	−3.726 (1)	1988	−4.876 (0)***	1997
$\ln Y_t^2$	−3.683 (1)	1988	−4.913 (0)***	1997
$\ln E_t$	−3.148 (1)	1989	−6.587 (0)*	1984
$\ln T_t$	−3.937 (1)	1976	−7.575 (0)*	1981

Note: Lag order is shown in parenthesis.
* Significant at 1% level of significance.
** Significant at 5% level of significance.
*** Significant at 10% level of significance.

Table 2
ARDL cointegration analysis.

Variable	$\ln C_t$	$\ln Y_t$	$\ln Y_t^2$	$\ln E_t$	$\ln T_t$
F-statistics	8.595**	3.635	3.420	11.766*	12.096*
Structural break	1990	1988	1988	1989	1976
Critical values#	1% Level	5% Level	10% Level		
Lower bounds	10.150	7.135	5.950		
Upper bounds	11.130	7.980	6.680		
Diagnostic test					
R^2	0.6720	0.9998	0.9998	0.8799	0.7377
Adj-R^2	0.3440	0.9995	0.9994	0.6999	0.3881
F-statistic	2.0498***	37.4092*	36.5700*	4.8881*	2.1104***

* Significant at 1% level.
** Significant at 5% level.
*** Significant at 10% level.
\# Critical values bounds are from Narayan [35] with unrestricted intercept and unrestricted trend.

Table 3
Results of Johansen cointegration test.

Hypothesis	Trace statistic	Maximum eigen value
$R=0$	115.9740*	57.35667*
$R\leq 1$	58.6173*	31.3741*
$R\leq 2$	27.2432	15.9318
$R\leq 3$	11.3113	9.4792
$R\leq 4$	1.83211	1.8321

* Significant at 1% level of significance.

emissions increase in the initial stage of economic growth and decline after a threshold point.[5] The earlier stage of Tunisian economic development is associated with slow economic activities. At such a stage, no environmental technologies are still used. At the same time, government policies are more directed towards economic development than to environmental problems. Consequently, CO_2 emissions rise with economic activities especially in big industrial cities such as Tunis, Sousse, Sfax and Gabès. After, the Law 2004-72 marked a critical turning point because it established energy efficiency as a national priority because of its contribution to sustainable development. The law outlines what actions are to be considered as constituting energy efficiency and places especial emphasis on obligatory periodical CO_2 emissions audits, regulation of the thermal performance of buildings, carbon dioxide test of car motors, transport planning in large agglomerations and promotion of renewable energy.

[5] This finding is consistent with Fodha and Zaghdoud [16] for Tunisia.

Table 4
Long and short runs results.

Dependent variable: $\ln C_t$			
Variable	Coefficient	Std. error	*t*-Statistic
Long run results			
Constant	−23.8490	8.8318	−2.7003**
$\ln Y_t$	4.9040	2.5298	1.9384***
$\ln Y_t^2$	−0.3286	0.1573	−2.0879**
$\ln E_t$	0.8137	0.1929	4.2170*
$\ln T_t$	0.2035	0.0638	3.1885*
Short run results			
Constant	0.0185	0.0100	1.8484***
$\Delta\ln Y_t$	5.7735	2.4950	2.3139**
$\Delta\ln Y_t^2$	−0.4064	0.1758	−2.3111**
$\Delta\ln E_t$	0.4972	0.2873	1.7302***
$\Delta\ln T_t$	0.1148	0.0932	1.2323
ECM_{t-1}	−0.7707	0.1397	−5.5149*
R^2	0.5220		
Adj-R^2	0.4496		
F-statistic	7.2085*		
Diagnostic test	*F*-statistic	Prob. value	
χ^2NORMAL	2.1106	0.3480	
χ^2SERIAL	0.8264	0.4469	
χ^2ARCH	0.0585	0.9431	
χ^2WHITE	1.9759	0.0760	
χ^2REMSAY	0.0904	0.7655	

* Significant at 1% level of significance.
** Significant at 5% level of significance.
*** Significant at 10% level of significance.

The impact of energy consumption on CO_2 emissions reveals that energy consumption is major contributor to energy pollutants. A 1% rise in energy consumption raises CO_2 emissions by 0.81% keeping other things constant. Energy demand in Tunisia is rising as a result of the growing economy. The country went for the first time into energy deficit in 1994 and after the production declined quite speedily and the deficit became marked and apparently persistent. In Tunisia, energy policy is dominated by energy efficiency and renewable energies over the last decades. Law no. 2004-72 on the rational use of energy defines the sensible use of energy as a national priority and as the most important element of a sustainable development policy. It states three principal goals: energy saving; the promotion of renewable energy and the substitution of forms of energy previously used, wherever this offers technical, economic and ecological benefits. Since 2005 with the adoption of above mentioned law and the creation of a national energy fund (subject of Law no. 2005-106) Tunisia set the political framework to increase energy efficiency and develop renewable energy sources. Decarbonization of the energy sector and a decoupling of economic growth and GHG emissions occurred. Moderated primary energy demand growth of 2.8% per year and the increase of the renewable share towards 4% of the consumption until 2011 are the key measures to reduce GHG emissions in the energy sector.[6]

The results note that trade openness has positive and significant impact on CO_2 emissions. All else is same, 0.2035% of CO_2 emissions are contributed with 1% increase in trade openness.[7]

[6] This finding is in line with Saboori et al. [45] for Indonesia, Shahbaz et al. [50] for Pakistan and Saboori et al. [46] for Malaysia. Similarly trade openness also adds in CO_2 emissions.

[7] However, this finding supports the view of Khalil and Inam [68] who probed that international trade is harmful to environmental quality in Pakistan and Halicioglu [22] who posited that foreign trade increases CO_2 emissions in Turkey. Sharma [69] also reported the same inference.

In 2009 the *Agence Nationale pour la Maitrise de l'Energie*[8] (ANME) described the energy policy in the context of the international efforts to reduce GHG emissions in a detailed development guide. The ANME aims at the production of energy from natural gas to reduce energy sector emissions. Between 2008 and 2010 contract based programs in the industrial sector, roll-out of fluorescent energy saving lamps in the residential sector, the certification of electric appliances, cogeneration, thermal insulation of buildings, solar water heating and wind power generation are politically set priorities for the energy sector development. In 1991, Tunisia acceded to the General Agreement on Tariffs and Trade (GATT) and is a member of World Trade Organization (WTO), thereby engaging in multilateral trade negotiations. Meanwhile, in 1995, Tunisia signed a free trade agreement with the EU, which stipulates a gradual removal of barriers to the entry of goods from the EU countries, until their total abolition. The EU remains Tunisia's first trading partner, currently accounting for 72.5% of Tunisian imports and 75% of Tunisian exports.[9] In 1998, Tunisia has signed other regional preferential trade agreement namely the Greater Arab Free Trade Area (GAFTA). In 2004, Tunisia has also signed the framework agreement for a multilateral trade agreement with Egypt, Jordan, and Morocco, known as the Agadir Agreement. The Agadir Agreement creates a potential market of over 100 million people across North Africa and into the Middle East. These agreements played a significant role in opening up Tunisia's trade, as evidenced by rising trend of its exports relative to GDP and the increase of Tunisia's trade openness (defined as the sum of imports and exports over GDP) from 68% in 1986 to almost 126% in 2008. In 2010, Tunisia occupied the first place in North Africa in terms of enabling trade and 38th worldwide moving up by three places from 2009.[10]

The lower part of Table 4 provides the details of the short run results. It is noted that the signs of both linear and nonlinear terms of real GDP per capita validates again the existence of inverted-U shaped curve in the short run. The results show that the long-run income elasticity for CO_2 emissions is less than the short-run elasticity for CO_2 emissions. This further claims that the existence of the EKC hypothesis. Energy consumption increase CO_2 emissions significantly and impact of trade openness on energy emissions is positive but it is statistically insignificant.

The coefficient of lagged error correct method (ECM_{t-1}) has negative sign and significant at 1% level of significance. The significance of lagged error term corroborates the established long run association between the variables. Furthermore, the negative and significant value of ECM_{t-1} implies that any change in CO_2 emissions from short run towards long span of time is corrected by 77.07% every year. Sensitivity analysis indicates that short run model passes all diagnostic tests i.e., LM test for serial correlation, ARCH test, normality test of residual term, white heteroskedasticity and model specification successfully. The results are shown in lower segment of Table 4. It is found that short run model does not show any evidence of non-normality of residual term and implies that error term is normally distributed with zero mean and covariance. Serial correlation does exist between error term and CO_2 emissions. There is no autoregressive conditional heteroscedasticity and same inference is drawn about white heteroscedasticity. The model is well specified proved by Ramsey RESET test.

The stability of long run parameters is tested by applying the CUSUM and CUSUMsq tests. The plots of both CUSUM and CUSUMsq statistics are reported in Figs. 2 and 3. These figures demonstrate that plots are of both tests are within the critical bounds and, therefore, confirm the stability of long-run estimates. Fig. 3 indicates that blue lines of CUSUMsq test cross the critical bounds at 5% significance level. It implies that the ARDL bounds testing's parameters are instable. Parameter instability is around the year 1995–1996 in CUSUMsq test but graph of CUSUM test does lie within critical bounds at 5% significance level. The break point in the economy can be detected and linked to free trade agreement signed with the EU in 1995, which stipulates a gradual removal of barriers to the entry of goods from the EU countries, until their total abolition.

The EU remains Tunisia's first trading partner, currently accounting for 72.5% of Tunisian imports and 75% of Tunisian exports.[11] Furthermore, we employ chow forecast test to examine the significance structural break points in the economy for the period 1995–1996. *F*-statistic indicates no structural break in the economy.[12] Chow forecast test is more reliable and preferable than graphs. Graphs mostly seem to mislead the results (Leow [66]). It is documented that there is no sign of structural break in sample period of the study.

5.1. The VECM Granger causality analysis

The presence of cointegration among the variables implies that causality relation must be existed at least from one side. The directional relationship between economic growth, energy consumption, trade openness and CO_2 emissions will provide help in articulating comprehensive policy to economic growth by controlling environment from degradation and utilize energy efficient technologies importing from advanced countries. We applied Granger causality test within the VECM framework to detect the causality between the variables. Table 5 reports the results of the VECM Granger causality analysis. The long run causality is captured by a significant *t*-test on a negative coefficient of the lagged error-correction term ECM_{t-1}. The jointly significant LR test on the lagged explanatory variables shows short-run causality.

The results reported in Table 5 reveal that the estimates of ECM_{t-1} are statistically significant with negative signs in all the VECMs except economic growth equations. Moreover, statistical significance of ECM_{t-1} indicates the shock exposed by system converging to long run equilibrium path at a high speed for trade openness equation (-0.7004) and energy consumption equation (-0.6768) the VECMs as compared to adjustment speed of CO_2 emissions equation (-0.5824) the VECM.

The results indicate that unidirectional causality running from economic growth to CO_2 emissions in long run. This finding corroborates that the EKC exists in case of Tunisia. The feedback effect is found between energy consumption and CO_2 emissions. Trade openness and CO_2 emissions Granger cause each other. Bidirectional causality also exists between trade openness and energy consumption. This finding is consistent with Sadorsky [47] for South America who also reported the feedback effect between trade (exports and imports) and domestic output. The unidirectional causality is also found running from economic growth to energy consumption. In short run, bidirectional causality is found between energy consumption and CO_2 emissions. Energy consumption Granger causes economic growth.

The Granger causality test does not determine the relative strength of causality effect beyond the selected time span (Shan [53]; Shahbaz et al. [67]). It is unable to indicate how much feedback exists from one variable to the other. To overcome the shortcoming of Granger causality test, we employ Innovative

[8] Tunisian National Agency for Energy Conservation.

[9] At the end of 2012, Tunisia will have access to the European Union advanced partner status.

[10] The Global Enabling Trade Report.

[11] Furthermore, in 1990, Tunisia signed the GATT agreements. The adherence to the WTO was achieved in 1995 (Tunisia has signed the statute of the International Renewable Energy Agency (IRENA) in April 2009.).

[12] Results are available upon request from authors.

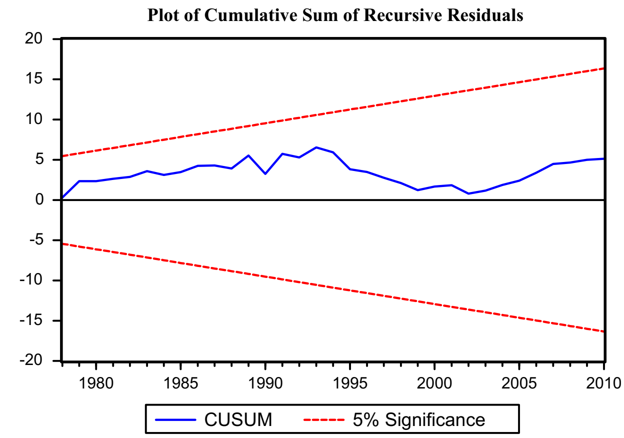


Fig. 2. Plot of cumulative sum of recursive residuals.

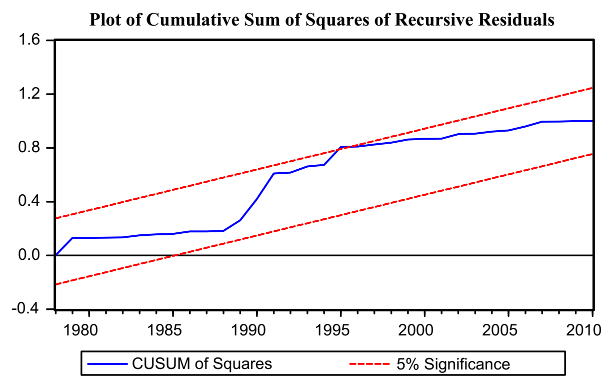


Fig. 3. Plot of cumulative sum of squares of recursive residuals. (The straight lines represent critical bounds at 5% significance level.) (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.)

Table 5
VECM causality analysis.

Dependent variable	Short run					Long run
	$\ln C_t$	$\ln Y_t$	$\ln Y_t^2$	$\ln E_t$	$\ln T_t$	ECM_{t-1}
$\ln C_t$	…	0.1076 [0.8984]	0.0239 [0.9767]	4.2858* [0.0242]	1.3039 [0.2880]	−0.5824* [−3.5051]
$\ln Y_t$	0.1140 [0.8926]	–	7.5780* [0.0001]	3.5071** [0.0437]	0.8156 [0.4526]	–
$\ln Y_t^2$	0.1371 [0.8724]	5.9579* [0.0010]	–	3.5002** [0.0454]	0.8352 [0.4344]	–
$\ln E_t$	5.1119** [0.0131]	1.2269 [0.3090]	1.0004 [0.3809]	–	0.1084 [0.8976]	−0.6768** [−2.3917]
$\ln T_t$	0.7192 [0.5458]	0.9567 [0.3968]	0.9070 [0.3957]	0.5890 [0.5618]	–	−0.7004* [−4.3240]

* Significant at 1% level of significance.
** Significant at 5% level of significance.

Table 6
Variance decomposition method.

Period	S.E.	$\ln C_t$	$\ln Y_t$	$\ln Y_t^2$	$\ln E_t$	$\ln T_t$
Variance decomposition of $\ln C_t$						
1	0.0445	100.0000	0.0000	0.0000	0.0000	0.0000
2	0.0491	95.2731	1.0588	0.8408	2.7154	0.1118
3	0.0523	90.3757	3.5994	0.7582	4.0923	1.1737
4	0.0558	79.5123	9.7814	2.8821	3.7181	4.1058
5	0.0613	67.0209	16.6202	3.12750	4.5049	8.7263
6	0.0649	59.9640	20.0541	5.6524	4.2104	10.1188
7	0.0675	55.4488	21.0545	8.6443	4.0952	10.756
8	0.0716	50.7392	20.3414	13.5897	5.5021	9.8274
9	0.0755	47.1073	19.2283	17.6236	6.7918	9.2488
10	0.0801	43.1985	17.6404	21.5590	9.0819	8.5200
Variance decomposition of $\ln Y_t$						
1	0.0224	0.6401	99.3598	0.0000	0.0000	0.0000
2	0.0282	5.5878	89.9195	0.7039	1.0751	2.7134
3	0.0338	3.9001	76.2913	4.2680	10.2109	5.3294
4	0.0395	4.2849	67.8636	9.11365	8.9457	9.7921
5	0.0454	4.6435	62.1836	14.7248	7.9190	10.5291
6	0.0510	4.8912	60.0555	16.4952	7.5487	11.0090
7	0.0564	5.1776	58.2621	17.4298	8.9283	10.2021
8	0.0621	6.5034	54.4854	18.7217	10.8881	9.4015
9	0.0683	8.0341	50.3422	20.266	12.8031	8.5542
10	0.0744	9.2188	47.1222	21.4936	14.0542	8.1110
Variance decomposition of $\ln Y_t^2$						
1	0.3308	0.6759	99.2610	0.0629	0.0000	0.0000
2	0.4194	5.4177	90.0166	1.1040	0.9249	2.5366
3	0.5001	3.8094	77.5702	3.8829	9.6857	5.0516
4	0.5838	4.2496	69.7003	8.0936	8.5146	9.4417
5	0.6703	4.6363	64.2832	13.2585	7.5945	10.2272
6	0.7535	4.8960	62.1595	14.9210	7.2842	10.7390
7	0.8356	5.2069	60.2973	15.8471	8.6874	9.9610
8	0.9213	6.5448	56.4738	17.1417	10.6429	9.1965
9	1.0140	8.0760	52.2703	18.7017	12.5691	8.3827
10	1.1069	9.2593	48.9824	19.9542	13.8382	7.9656
Variance decomposition of $\ln E_t$						
1	0.0295	15.4033	18.4541	15.4609	50.6816	0.0000
2	0.0336	27.7207	14.9081	12.7352	40.8274	3.8084
3	0.0404	19.4140	10.9853	28.6574	37.6942	3.2489
4	0.0458	15.5124	16.2010	28.4834	29.5585	10.2445
5	0.0511	12.4865	23.0822	29.0983	24.1471	11.1857
6	0.0553	10.6837	26.0570	28.7543	20.9469	13.5578
7	0.0598	9.7938	27.0697	30.4366	20.2351	12.4645
8	0.0645	10.6287	26.2032	32.1432	19.3918	11.6329
9	0.0698	11.1439	24.9049	33.7213	19.8682	10.3616
10	0.0747	11.5329	23.5654	34.8405	20.2631	9.7978
Variance decomposition of $\ln T_t$						
1	0.0596	12.6175	1.7214	1.6530	3.3415	80.6663
2	0.0882	27.4219	8.4410	1.6840	14.7440	47.7088
3	0.0973	25.0521	8.5960	1.5335	24.1910	40.6273
4	0.1024	22.6389	13.7502	2.4004	23.7796	37.4307
5	0.1058	21.8294	17.4439	2.8371	22.4457	35.4437
6	0.1091	21.4600	16.8606	3.0987	25.2202	33.3603
7	0.1141	21.1023	15.5175	6.2009	26.4027	30.7763
8	0.1182	20.3947	14.6010	10.1885	25.7106	29.1050
9	0.1201	19.9173	14.1479	12.3144	25.0346	28.5856
10	0.1207	19.6993	14.1635	12.9537	24.8159	28.3673

Accounting Approach (IAA) to investigate the dynamic causality relationships among economic growth, energy consumption, trade openness and CO_2 emissions. IAA avoids the problem of endogeneity and integration of the series. This approach is superior to the VECM Granger causality test because the latter only shows causal relationship between the variables within the sample period while the former illustrates the extent of causal relationship ahead the selected sample period. It is pointed by Pesaran and Shin [37] that generalized forecast error variance decomposition method shows proportional contribution in one variable due to innovative shocks stemming in other variables. The main advantage of this approach is that like orthogonalized forecast error variance decomposition approach; it is insensitive with ordering of the variables because ordering of the variables is uniquely determined by VAR system. Further, the generalized forecast error variance decomposition approach estimates the simultaneous shock affects. Engle and Granger [13] and Ibrahim [23] argued that with VAR framework, variance decomposition approach produces better results as compared to other traditional approaches. The results of variance decomposition approach are described in Table 6. The empirical evidence indicates that a 17.64% (21.55%) portion of CO_2 emissions is contributed by its own innovative shocks and one standard deviation shock in real GDP per capita (squared of real GDP per capita). The contribution

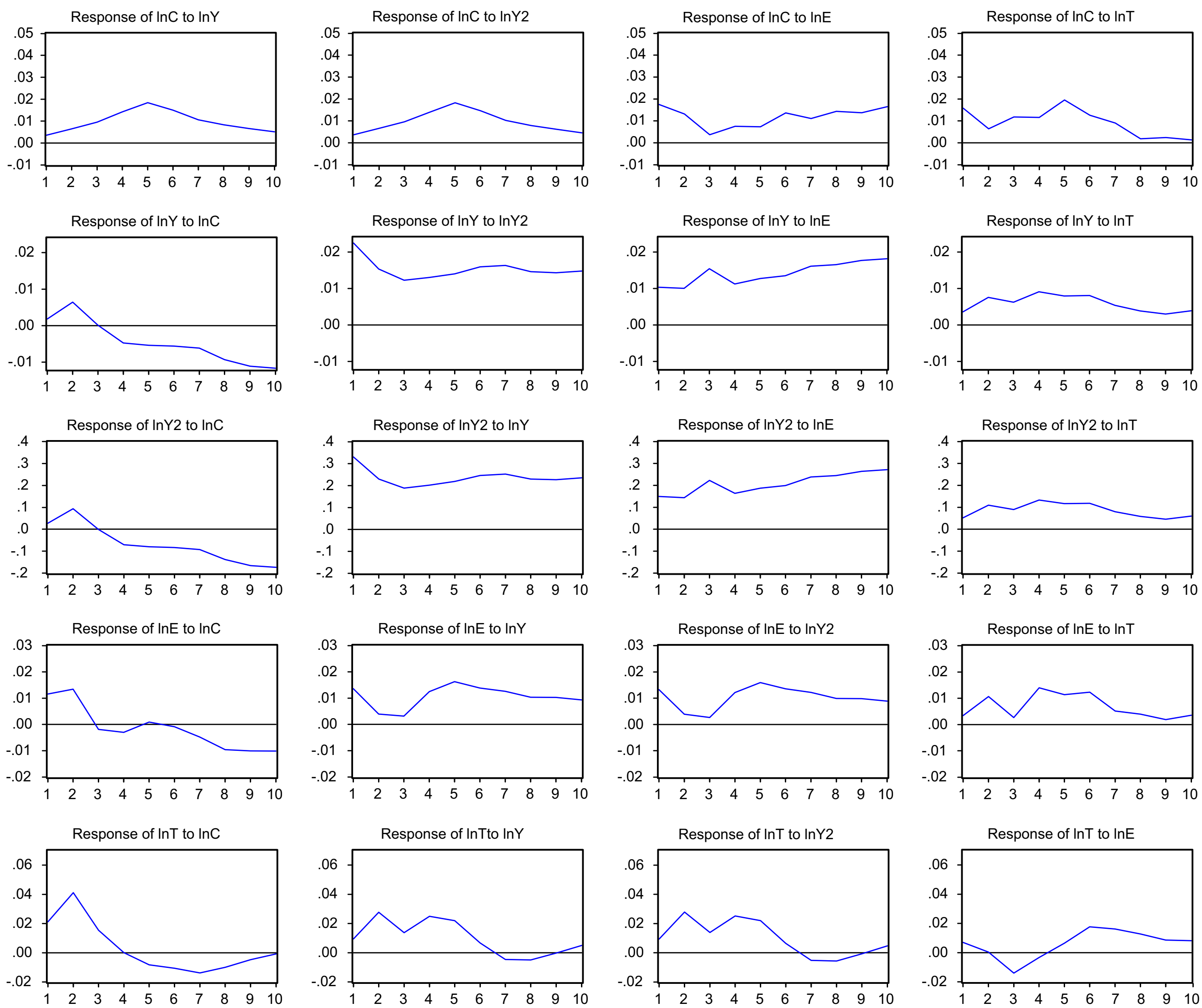


Fig. 4. Impulse response function (IRF).

of energy consumption and trade openness is minimal i.e., 9.08% and 8.52% respectively. CO_2 emissions, energy consumption and trade openness explain economic growth by 9.21%, 14.05% and 8.11% respectively. A standard shock in linear and nonlinear terms of real GDP per capita (economic growth) contributes to energy consumption by 23.56% and 34.84% respectively. CO_2 emissions and trade openness explain energy consumption by 11.53% and 9.79% respectively and residual (20.26%) is contributed by own standard shock in energy consumption.

One standard shock in CO_2 emissions (linear and nonlinear terms of real GDP per capita) and energy consumption fund to trade openness by 0.12%, (14.16% and 12.95%) and 24.81% respectively. Overall results point out that economic growth Granger causes CO_2 emissions and energy consumption. Trade openness is Granger cause of energy consumption.

The impulse response function is alternative of variance decomposition method show how long and to what extent dependent variable reacts to shock stemming in independent variables (see Fig. 4). The results indicate that the response in CO_2 emissions due to forecast error stemming in economic growth initially rises, goes to peak and then starts to decline after 5th time horizon. This presents the phenomenon of environmental Kuznets curve or inverted U-shaped relationship between economic growth and CO_2 emissions. The response in CO_2 emissions is positive but fluctuating due forecast error in energy consumption and trade openness. The forecast error in energy consumption (CO_2 emissions) and trade openness stimulates (declines) economic growth. The forecast error arising in economic growth and trade openness intends energy consumption to respond positively but the negative response is found in energy consumption due to shock in CO_2 emissions. The response in trade openness is fluctuating due to one standard forecast error in CO_2 emissions, economic growth and energy consumption.

6. Conclusion and policy implications

This paper deals with empirical investigation between CO_2 emissions and economic growth by incorporating energy consumption and trade openness as potential determinants of CO_2 emissions function in case of Tunisia over the period of 1971–2010. We have applied structural break unit root test and long run relationship between the variables is investigated by applying the ARDL bounds testing approach to cointegration. Causal relationship among economic growth, energy consumption, trade openness and CO_2 emissions is scrutinized by applying the VECM Granger causality approach and robustness of causality analysis is examined by innovative accounting approach.

According to the results, the cointegration exists between the variables for long run relationship. Furthermore, the EKC hypothesis exists between economic growth and CO_2 emissions. In addition, energy consumption adds in CO_2 emissions and trade openness contributes to CO_2 emissions. The causal analysis reveals that overall results point out that economic growth Granger causes CO_2 and energy consumption. In this work shown that trade openness is Granger cause of energy consumption.

The findings of this paper suggest that Tunisia will need to implement specific policies to reduce emissions, especially fossil fuel carbon dioxide (CO_2). The appropriate choice of instrument, or instruments, to reduce CO_2 emissions is, however, a complex policy decision. Our results indicated that energy consumption is a major contributor to energy pollutants. Recently, Tunisian legislation (Law no. 2004-72 amended by law no. 2009-7) on energy conservation has provided incentive for energy-efficient use. However, the available energy resource continues to decline and Tunisia remains an oil dependent country and the legislation on energy conservation necessitates new instruments to comply with sustainable development. Therefore, the government has a crucial role to play in encouraging more efficient use of energy and in promoting renewable energy sources. In order to obtain the sustainable energy policy, the Tunisian government planned to increase the share of renewable energies from 2010 below 1% of the total energy consumption to about 4% in 2011. Moreover, the share of renewable energies in the electricity sector is planned to increase to 10% of the total capacity in the same time frame. These goals have not been reached. Lastly, the Ministry of Environment and Sustainable Development offered the first Solar Energy Plan to encourage the use of renewable energy sources. The energy savings expected to result from this first National Plan could reach 22% for 2016 with an abatement of 1.3 million t per year of CO_2. This national program could be consolidated by a carbon pricing policies that represent the most important instruments for promoting the development and deployment of clean technologies. However, in Tunisia, supplementary institutional regulations may be needed to help overcome market barriers to large clean-energy investments. Regulatory instruments can provide incentives for clean technology diffusion. Regulatory policies can also reduce the demand for electricity, and direct fuel usage, through setting standards for energy intensity.

Price reforms will save large quantities of energy, especially in the long-run and can make a substantial reduction in GHG emissions. All energy prices in Tunisia are subsidized, but unevenly. The total value of subsidies for petroleum products is estimated at US$1220 million in 2007, or around US$126/toe on average. The cost of subsidizing energy rose dramatically; in 2003, the subsidies from the state budget to energy products were around US$152 million (an eightfold increase in four years). Then, a reduction of the subsidies, granted by Tunisian government to the energy sector, should mitigate CO_2 emissions.

The empirical evidence indicates too that trade openness has positive and significant impact on CO_2 emissions. This scale effect signifies that the increase of export level from Tunisia to European Union requires more production which will generate more CO_2 emissions. This result confirms those reported by Managi [73] where trade liberalization in developed and developing countries increasing levels of CO_2. The acceleration of international trade contributes to the increase in per capita income in Tunisia and eventually the government will give more attention to the quality of the environment that becomes priority for Tunisian government's agenda (after the promulgation of law no. 2004-72). Trade openness can improve the state of the environment by encouraging the import of cleaner technologies (technique effect), for industry and transport sectors, which reduce CO_2 emissions and allow also for an increase the renewable energy use.

References

[1] Akbostanci E, Tunc GI, Türüt-Asik S. Pollution haven hypothesis and the role of dirty industries in Turkey's exports. ERC Working Paper 0403. Middle East Technical University, Economic Research Center; February 2004.
[2] Ang JB. CO_2 emissions, energy consumption, and output in France. Energy Policy 2007;35:4772–8.
[3] Ang JB. Economic development, pollutant emissions and energy consumption in Malaysia. J Policy Model 2008;30:271–8.
[4] Antweiler W, Copeland B, Taylor S. Is free trade good for the environment? Am Econ Rev 2001;91:877–908.
[5] Bartleet M, Gounder R. Energy consumption and economic growth in New Zealand: results of trivariate and multivariate models. Energy Policy 2010;38:3508–17.
[6] Baum CF. A review of Stata 8.1 and its time series capabilities. Int J Forecast 2004;20:151–61.
[7] Belloumi M. Energy consumption and GDP in Tunisia: cointegration and causality analysis. Energy Policy 2009;37:2745–53.
[8] Cheung Y-W, Lai K. A fractional cointegration analysis of purchasing power parity. J Bus Econ Stat 1993;11:103–12.
[9] Copeland BR, Taylor MS. North–South trade and the environment. Q J Econ 1994;109:755–87.
[10] Copeland BR, Taylor MS. Trade and transboundary pollution. Am Econ Rev 1995;85:716–37.
[11] Dijkgraaf E, Vollebergh H. A note on testing for environmental Kuznets curves with panel data. Others 0409001, EconWPA. St. Louis: Washington University; 2004.
[12] Egli H. The environmental Kuznets curve: evidence from time series data for Germany. CER-ETH Economics Working Paper 03/28. Zurich: Center of Economic Research, Swiss Federal Institute of Technology (ETH); 2004.
[13] Engle RF, Granger CWJ. Cointegration and error correction representation: estimation and testing. Econometrica 1987;55:251–76.
[14] ETAP. Tunisian company of oil activities annual report; 2010. ⟨http://www.etap.com.tn/fileadmin/templates/etap/rapports/Rapport_ETAP_2010_Fr.pdf⟩.
[15] European Commission. Tunisia-trade statistics; 2012. ⟨http://trade.ec.europa.eu/doclib/docs/2006/september/tradoc_122002.pdf⟩.
[16] Fodha M, Zaghdoud O. Economic growth and pollutant emissions in Tunisia: an empirical analysis of the environmental Kuznets curve. Energy Policy 2010;38:1150–6.
[17] Frankel JA, Rose AK. Is trade good or bad for the environment? sorting out the causality Rev Econ Stat 2005;87:85–91.
[18] Gamper-Rabindran S, Jha S. Environmental impact of India's trade liberalization; 2004. ⟨http://unpan1.un.org/intradoc/groups/public/documents/APCITY⟩.
[19] Gonzalo J, Lee T-H. Pitfalls in testing for long-run relationships. J Econom 1998;86:129–54.
[20] Granger CWJ. Investigating causal relations by econometric models and cross-spectral methods. Econometrica 1969;37:424–38.
[21] Grossman GM, Krueger AB. Environmental impacts of a North American Free Trade Agreement. NBER Working Paper, no. 3914. Washington; 1991.
[22] Halicioglu F. An econometric study of CO_2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy 2009;37:1156–64.
[23] Ibrahim M. Sectoral effects of monetary policy: evidence from Malaysia. Asian Econ J 2005;191:83–102.
[25] Johansen S. Statistical analysis of cointegration vectors. J Econ Dyn Control 1988;12:231–54.
[26] Johansen S, Juselius K. Maximum likelihood estimation and inference on cointegration with applications to the demand for money. Oxf Bull Econ Stat 1990;52:169–210.
[27] Kuznets S. Economic growth and income inequality. Am Econ Rev 1955;45:1–28.
[28] Lean HH, Smyth R. CO_2 emissions, electricity consumption and output in ASEAN. Appl Energy 2010;87:1858–64.
[29] R.E.B. Lucas, D. Wheeler and H. Hettige, Economic development, environmental regulation, and the international migration of toxic industrial pollution 1960–88, 1992, WPS no. 1062, World Development Report, The World Bank. Washington, DC 20433 USA. Policy, Research working papers; no. WPS 1062. World Development Report.
[30] Lütkepohl H. Structural vector autoregressive analysis for cointegrated variables. AStA: Adv Stat Anal 2006;90:75–88.
[31] Mani MS, Jha S. Trade liberalization and the environment in Vietnam. Policy Research Working Paper 3879. World Bank; April 2006.
[32] Menyah K, Wolde-Rufeal Y. Energy consumption, pollutants emissions and economic growth in South Africa. Energy Consum 2010;32:1374–82.
[33] Ministry of the Environment and Sustainable Development, Republic of Tunisia. Initial communication of Tunisia under the United Nations Framework Convention on Climate Change; October 2001.
[34] Nahman A, Antrobus G. Trade and the environmental Kuznets curve: is Southern Africa a pollution haven? S Afr J Econ 2005;73:803–14.
[35] Narayan PK. The saving and investment nexus for China: evidence from co-integration tests. Appl Econ 2005;37:1979–90.
[36] Nasir M, Rehman F-U. Environmental Kuznets curve for carbon emissions in Pakistan: an empirical investigation. Energy Policy 2011;39:1857–64.
[37] Pesaran MH, Shin Y. An autoregressive distributed lag modelling approach to cointegration analysis. In: Strom S, editor. Econometrics and economic theory in the 20th century (Chapter 11): the Ragnar Frisch centennial symposium. Cambridge: Cambridge University Press; 1999.

[38] Pesaran MH, Shin Y, Smith RJ. Bounds testing approaches to the analysis of level relationships. J Appl Econom 2001;16:289–326.
[45] Saboori B, Sulaiman JB, Mohd S. An empirical analysis of the environmental Kuznets curve for CO_2 emissions in Indonesia: the role of energy consumption and foreign trade. Int J Econ Finance 2011;4:243–51.
[46] Saboori B, Sulaiman JB, Mohd S. Economic growth and CO_2 emissions in Malaysia: a cointegration analysis of the environmental Kuznets curve. Energy Policy 2012;51:184–91.
[47] Sadorsky Perry. Energy consumption, output and trade in South America. Energy Econ 2012;34:476–88.
[48] Sari R, Soytas U. The growth of income and energy consumption in six developing countries. Energy Policy 2007;35:889–98.
[49] Shahbaz M. Income inequality-economic growth and non-linearity: a case of Pakistan. Int J Soc Econ 2010;37:613–36.
[50] Shahbaz M, Lean HH, Shabbir MS. Environmental Kuznets curve hypothesis in Pakistan: cointegration and Granger causality. Renew Sustain Energy Rev 2012;16:2947–53.
[51] Shahbaz M, Lean HH. Does financial development increase energy consumption? The role of industrialization and urbanization in Tunisia Energy Policy 2012;40:473–9.
[52] Shahbaz M, Mutascu M, Azim P. Environmental Kuznets curve in Romania and the role of energy consumption. Renew Sustain Energy Rev 2013;18:165–73.
[53] Shan J. Does financial development 'lead' economic growth? A vector autoregression approach Appl Econ 2005;37:1353–67.
[54] Song T, Zheng T, Tong L. An empirical test of the environmental Kuznets curve in China: a panel cointegration approach. China Econ Rev 2008;19:381–92.
[55] Stern DI, Common MS, Barbier EB. Economic growth and environmental degradation: the environmental Kuznets curve and sustainable development. World Dev 1996;24:1151–60.
[56] Stock JH, Watson MW. A simple estimator of cointegrating vectors in higher order integrated systems. Econometrica 1993;61:783–820.
[57] Tiwari AK. Energy consumption, CO_2 emissions and economic growth: evidence from India. J Int Bus Econ 2011;12:85–122.
[58] Tunisian National Agency for Energy Conservation (ANME). The renewable energy and energy efficiency plan 2008–2011; 2008.
[59] Tunisian National Agency for Energy Conservation (ANME). Tunisian Solar Plan 2009–2016; 2009.
[60] Turner P. Response surfaces for an *F*-test for cointegration. Appl Econ Lett 2006;13:479–82.
[61] Uddin MGS, Bidisha SH, Ozturk I. Carbon emissions, energy consumption and economic growth relationship in Sri Lanka. Energy Sources, Part B: Econ, Plan, Policy 2014 (forthcoming).
[62] Wyckoff AW, Roop JM. The embodiment of carbon in imports of manufactured products: implications for international agreements on greenhouse gas emissions. Energy Policy 1994;22:187–94.
[63] Yeh C-C. The relationships between the CO_2 emissions and national income under quantiles inference. Asian J Nat Appl Sci 2012;1:55–66.
[64] Zivot E, Andrews D. Further evidence on the great crash, the oil price shock, and the unit root hypothesis. J Bus Econ Stat 1992;10:251–70.
[65] World Development Indicators. Washington, DC: World Bank; 2012.
[66] Leow YG. A reexamination of the exports in Malaysia's economic growth: after Asian financial crisis, 1970–2000. Int J Manag Sci 2014;11:79–204.
[67] Shahbaz M, Zeshan M, Afza T. Is energy consumption effective to spur economic growth in Pakistan? New evidence from bounds test to level relationships and Granger causality tests Econ Model 2012;23:2310–9.
[68] Khalil S, Inam Z. Is trade good for environment? A unit root cointegration analysis? Pak Dev Rev 2006;45:1187–96.
[69] Sharma SS. Determinants of carbon dioxide emissions: empirical evidence from 69 countries. Appl Energy 2011;88:376–82.
[71] Energy Information Administration; 2011. ⟨http://www.eia.gov/forecasts/aeo/⟩.
[72] Energy Information Administration; 2012. ⟨http://www.eia.gov/forecasts/aeo/⟩.
[73] Managi S. Trade liberalization and the environment: carbon dioxide for 1960–1999. Econ Bull 2004;17:1–5.
[74] Shahbaz M, Ozturk I, Afza T, Ali A. Revisiting the environmental Kuznets curve in a global economy. Renew Sustain Energy Rev 2013;25:494–502.
[75] Shahbaz M, Hye QMA, Tiwari AK, Leitão NC. Economic growth, energy consumption, financial development, international trade and CO_2 emissions in Indonesia. Renew Sustain Energy Rev 2013;25:109–21.
[76] Shahbaz M, Mutascu M, Azim P. Environmental Kuznets curve in Romania and the role of energy consumption. Renew Sustain Energy Rev 2013;18:165–73.
[77] Shahbaz M, Leitão NC. Portuguese carbon dioxide emissions and economic growth: a time series analysis. Bull Energy Econ 2013;1:1–7.